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The diet of the burrowing owl in open habitats of southern Brazil

Dieta da coruja-buraqueira em ambientes abertos do sul do Brasil

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Abstract

Athene cunicularia's diet is composed of vertebrates and invertebrates, whose relative frequencies can change in space or time. We analyse habitat and temporal variation in the weight and the composition of prey in bird pellets. We collected 396 pellets from nine owl couples for six months and in three open habitats: near forest, far from forest, and urban. Mean pellet weight was 1.03 g. August showed pellets 15% heavier and March 22% lighter than average, differing from the other months. Regarding composition of prey, vertebrates occurred more in the pellets during June, July and August, while invertebrates showed higher frequency in summer months in open habitats far from forest. At the lower taxonomic level, we identified the presence of mammals, serpents, amphibians, birds, beetles, ants, spiders, grasshoppers, woodlice, molluscs and cockroaches in the pellets. The diet during winter in open habitats far from forest showed higher presence of mammals, while summer months in open habitats near forest and in urban habitats showed more hymenopterans. The results showed that *A. cunicularia* preys on a wide spectrum of prey, but we found some preference for specific prey depending on the season and on the open habitat types.

Keywords: Atlantic Forest, pellets, spatial effect, time effect.

Resumo

A dieta da coruja-buraqueira *Athene cunicularia* é composta de vertebrados e invertebrados, cujas frequências relativas podem mudar no tempo e/ou espaço. Analisamos variações ambientais e temporais no peso e na composição de presas nas pelotas dessas aves. Coletamos 396 pelotas de nove casais durante seis meses em três áreas abertas no sul do Brasil: próximas de floresta, afastadas de floresta e urbanas. O peso médio das pelotas foi de 1,03 g. Agosto apresentou pelotas 15% mais pesadas, enquanto março teve pelotas 22% menos pesadas, comparadas com a média, ambos se diferenciando dos outros meses. Com relação à composição de presas, vertebrados ocorreram com mais frequência em junho, julho e agosto, enquanto invertebrados nos meses mais quentes em áreas abertas afastadas da floresta. Ao menor nível taxonômico, identificamos mamíferos, serpentes, anfíbios, aves, besouros, formigas, aranhas, gafanhotos, tatuzinhos-de-jardim, moluscos e baratas nas pelotas. A dieta no inverno apresentou maior frequência de mamíferos em áreas abertas afastadas de floresta, enquanto aquela do verão apresentou mais himenópteros em áreas abertas perto de floresta e em áreas urbanas. Os resultados mostram que *A. cunicularia* preda em um amplo espectro de presas, mas encontramos algumas preferências para presas específicas, dependendo da estação e do tipo de área aberta.

Palavras-chave: Mata Atlântica, pelotas, efeito espacial, efeito temporal.

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Introduction

Athene cunicularia (Molina 1782) – the burrowing owl – occurs in areas of short grasses or other sparse vegetation (Coulombe, 1971). It nests and roosts in burrows, which can be self-made or abandoned by other animals. Individuals are small (~ 23 cm) with a rounded head with no tuft, a short tail and long legs (Sick, 2001; Sigrist, 2006). Its activity is mainly diurnal and at dusk, which differentiates it from other owls (Motta-Junior and Alho, 1998).

Similarly to other owls, *A. cunicularia* produces pellets that can be found under perches or near the owl's nest (Matter, 2010). These are masses of undigested parts of bird's food and may contain insect bones, exoskeletons, feathers, fur, scales, and skins (Sick, 2001; Bastian *et al*., 2008; Menezes and Ludwig, 2013). At the end of the day and/or during the night, the owl regurgitates one or two pellets, which may vary depending on the food availability (Motta-Junior and Alho, 2000; Matter, 2010). Regurgitated material may be used to study owl food habits without the need to sacrifice the individuals (Menezes and Meira, 2012).

Small rodents appear as the main group of vertebrates consumed by *A. cunicularia* followed by birds, anurans and reptilians (Motta-Junior and Alho, 2000; Carevic *et al*., 2013; Cadena-Ortíz *et al*., 2016). Invertebrates are often abundant and may make up till 90% of owl pellets (Zilio, 2006; Menezes and Ludwig, 2013). Coleoptera, Orthoptera, Hymenoptera, Spider and Scorpionida are the most common orders in the pellets (Motta-Junior and Alho, 2000; Menezes and Ludwig, 2013; Cadena-Ortíz *et al*., 2016).

As a generalist species *A. cunicularia* can adapt very well to human made environments (Motta-Junior, 2006; Menezes and Meira, 2012). This trait can facilitate its survivor in urban and rural areas where high concentrations of invertebrates are often found (Soares *et al*., 1992; Perillo *et al*., 2011). The resource use by *A. cunicularia* may also help in the control of prey in urban environments, maintaining prey populations at equilibrium (Menezes and Meira, 2012; Menezes and Ludwig, 2013). In the present study, we characterize the diet of *A. cunicularia* individuals and compare *A. cunicularia* pellets' weights and the compositions of food prey during six months in two rural and one urban open habitats of southern Brazil. Our hypothesis is that individuals living in open habitats near fragments of forest have a different composition of food items because there is a mixture of prey from both environments. We also believe that the diet of this species shows higher presence of invertebrates in summer due to the greater availability of this food resource.

Material and methods

Study area

Owl pellets were sampled in the municipalities of Águas de Chapecó (27º04'13' S - 52º59'12' W, altitude = 238 m) and São Carlos (27º04'39' S -53º00'14' W, altitude = 264 m) in southern Brazil (Figure 1). Climate in the region is classified as temperate, without dry season and with hot summer - Cfa Köppen - Geiger classification (Alvares *et al*., 2014). Annual temperatures range from 13ºC to 27ºC with an average of 20ºC. Annual precipitation ranges from 1,700 mm to 1,900 mm (Pandolfo *et al*., 2002).

The area belongs to the Atlantic Forest biome and is historically covered by deciduous forest, which was converted during human colonization started in the beginning of 20th century (Renk, 2014). Landscape is composed of remnants of deciduous forest (Klein, 1978) embedded in a mosaic of various man-made patches, notably urban, pasture, and agriculture. Urban habitats are characterized by the presence of one medium (200,000 inhabitants) and other small sized cities. Pasture and agriculture patches were created and are maintained by a strong agroindustry activity initiated at the 1950s. The historical landscape conversion set adequate conditions to the spread of *A. cunicularia*, a species strongly linked to open landscapes.

We selected three open habitats types to analyse the *A. cunicularia* diet, each of them with three replicates. The rural open habitats near forest (Rural 1) are characterized by the presence of a forest fragment in the landscape at least at 50 m of the nests. This open habitat type has been used mainly for cattle breeding. A second type of rural open habitats is characterized by the presence of a forest fragment at least at 250 m far from forest (Rural 2). These habitats have been also used mainly for cattle breeding. The third type is represented by urban open habitats (Urban), being characterized by the presence or not of forest fragments at different distances and used for agriculture, cattle breeding or abandoned grasslands (Figure 1).

Pellet collections

We sampled two pellets of one couple of *A. cunicularia* in the nine open habitats on a weekly basis in June, July, August, and December 2015, and February and March 2016, totalling 396 pellets. Pellets were collected around 3 m from the nests or perches used by the owls. The material was stored in plastic bags, identified, and dehumidified in muffle (38ºC) for 48 hours. Individual pellet total mass was measured on a precision scale (Model ARD110, class II, manufactured by OHAUS Corporation) with a precision of 0.01 g. We also weighted the mass of five taxa in the pellets separately: vertebrates, invertebrates, plant (seeds, leaves and fragments),

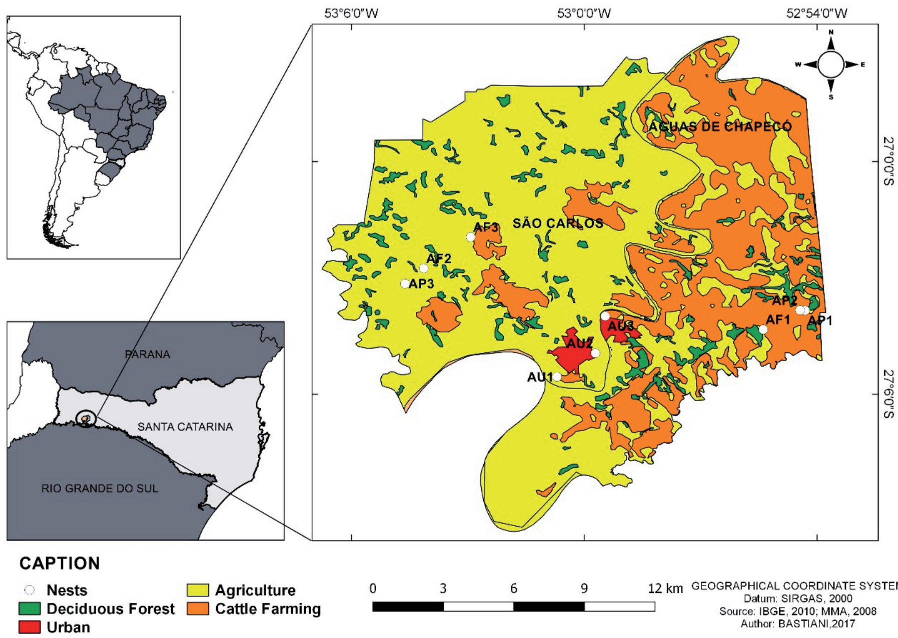

Figure 1. Location of the nests of *Athene cunicularia* in the municipalities of Águas de Chapecó and São Carlos, Santa Catarina, southern Brazil. (AF) rural open habitats at a maximum distance of 50 m from nearest forest fragment (Rural 1); (AP) rural open habitats at a maximum distance of 250 m from nearest forest fragment (Rural 2); and (AU) urban open habitats (Urban).

mineral (rock fragments), and inorganic residue (plastic, glass, styrofoam, etc.) (Bastian *et al*., 2008). We further refined the classification of food items based only on the presence of the taxa Mammalia, Serpentes, Amphibia, Aves, non-identified vertebrates, Coleoptera, Hymenoptera, Orthoptera, Oniscidea, Lepidoptera, Mollusca, Blattodea, and non-identified invertebrates.

Vertebrates were identified based on Hildebrand (1995), and invertebrates were identified based on Ribeiro-Costa and Rocha (2002) and on Brusca and Brusca (2007). To avoid bias on items' classification, we consulted a specialist researcher whenever needed.

Data analyses

The time and open habitat type effects on the three response variables (1) total food weight (univariate), (2) prey taxon weights (quantitative multivariate), and taxon presences (binary multivariate) were analysed by means of one two-way permutational analyses of variance and two two-way permutational multivariate analysis of variance, respectively (Pillar and Orlóci,1996). ANOVA was based on the resemblance matrix between the times and between the open habitats based on Euclidean distance for prey taxon weights. MANOVAs were based on chord distance for weights of prey in the pellets, and Jaccard for taxa presence (transformed into squared dissimilarities) (Legendre and Legendre, 2012). In permutational analysis of variance the test criterion is the sum of squared dissimilarities between groups of sampling units under time or open habitat factors and the significance of the observed result is tested by means of randomization tests (Pillar and Orlóci, 1996) (1,000 iterations).

We performed two principal coordinate analyses (PCoA) with the compositional data to graphically visualize the patterns of time and open habitat type distribution of pellets based on weights of different prey items and prey taxon presences. We used the centroid of the distribution of the categorical variables scores in the ordination diagram to represent the replicates of the two factors. The response variables were projected on the ordination diagram based on the correlation between each one of them and the two ordination axes, allowing the interpretation of variation in the ordination space based on the higher correlation coefficients (typically ≥ 0.5) (Pillar, 1999).

Results

Invertebrates were the most common items found in the pellets of the burrowing owls showing an average of 81% of relative frequency in the three open habitats and 81.3% in the six months (Tables 2 and 3). Beetles occurred 32.3% in open habitats and 32.5% in the six months. Non-identified invertebrates were the second most common item, followed by the hymenopterans. Vertebrates occurred at an average frequency of 19% in the open habitats and 18.7% in the six months. As expected for vertebrates, mammals were the most common taxon, with 15.7% average frequency in the open habitats and 15.7% in the six months (Tables 2 and 3).

The mean weight of the 396 pellets was 1.03 g (± 0,02 standard error). There was a significant time effect on the mean pellet weights (Table 1, Figure 2). August showed the higher pellet weight (1.21 g), whilst March showed the lowest mean weight (0.81 g). We found different patterns of prey compositions based on their weights and on the presence of different taxa. There was a significant interaction between time and open habitat effect on the composition of different prey based on their weights (Table 1, Figure 3). The composition of pellets on the Rural 2 open habitats was described mainly by the biomass of invertebrates during February and March, while composition of winter months showed more vertebrate biomasses in the pellets of Urban open habitats. The composition of pellets based on the presence of taxa was affected by time and open habitat factors, but there was no significant interaction (Table 1, Figures 4 and 5).

Composition of pellets in June showed more mammals and blattodeans, while beetles contributed more to the composition in July. In December, there were more hymenopterans, amphibians, orthopterans, serpents, and oniscideans, while the composition of pellets collected in March and February showed more molluscs, lepidopterans, birds, and non-identified invertebrates. Overall, composition of pellets in warmer months showed the presence of more taxa. Composition of pellets on Rural 2 areas showed only three taxa: blattodeans, coleopterans, and mammals. In that sense, pellets in Rural 1 and Urban open habitats showed the presence of more taxa compared to Rural 2 areas. Mammals and hymenopterans showed higher correlation with the two ordination axes, suggesting that these two items were more important to describe the differences between months and open habitats (Figures 4 and 5).

Discussion

Our initial hypotheses were partially confirmed by the results. The composition of prey items in rural open habitats near forest was different from the other habitat types. Overall, *A. cunicularia* diet has a broad prey range, which includes insects, molluscs, amphibians, reptiles, birds, and mammals similarly to other studies in the Neotropical region (Bellocq, 1987, 1988; Martins and Egler, 1990;

Table 1. Results of two-way permutational (M)ANOVAs comparing the pellets of *A. cunicularia* mean total weights, composition of prey item weights, and composition of taxon presence between six months and three open habitats in southern Brazil.

	Source of variation	Sum of squares	P
Total weights	Time	5.51	0.001
	Open habitat	0.38	0.416
	Time × open habitat	1.64	0.653
Pellet composition based on prey weights	Time	14.28	0.001
	Open habitat	2.073	0.033
	Time × open habitat	8.174	0.001
Pellet composition based on taxon presence	Time	6.30	0.001
	Significant contrasts		
	Jun × Jul	0.87	0.029
	Jun × Dec	0.78	0.040
	Jun × Mar	1.92	0.002
	Jul × Aug	1.57	0.003
	Jul × Feb	1.08	0.007
	Aug × Dec	1.13	0.015
	Aug × Feb	2.02	0.001
	Aug × Mar	3.21	0.001
	Dec × Feb	1.38	0.005
	Feb × Mar	2.04	0.001
	Open habitat	1.51	0.016
	Urban × Rural 1	1.17	0.006
	Time × open habitat	5.41	0.999

Table 2. *Athene cunicularia* consumed prey items collected in six months of 2015 and 2016 in southern Brazil. Total and relative biomasses of five classes of prey, and relative frequency of taxon presence.

Prey categories	Biomass (g)	Relative frequency (%)					
		Jun	Jul	Aug	Dec	Feb	Mar
Vertebrates	0.39	19.2	21.2	22.6	18.4	16.7	13.8
Amphibia		0	0.5	0	0.5	1	0
Aves		0.5	0.9	0.4	0	0	0
Mammalia		17.6	16.2	18.8	15.6	12.3	13.2
NI		1.1	0.5	0.9	1	3	0.7
Serpentes		0	3.15	2.6	1.4	0.5	0
Invertebrates	0.56	80.8	78.8	77.3	81.7	83.2	86.2
Blattodea		0	0	1.3	0.5	0	1.3
Coleoptera		29.7	32	30.3	32.6	35.5	34.9
Hymenoptera		16.5	10.4	12.8	13.3	6.9	6.6
Lepidoptera		0	1.4	0.9	1	0	0.6
Mollusca		0	0	0	0.5	2	5.3
NI		29.7	32	30.3	33	35.5	35.5
Oniscidea		0	0	0.4	0.5	1	0
Orthoptera		5	3.2	1.3	0.5	2.5	2
Vegetal	0.04						
Mineral	0.02						
Inorganic	0.006						
Total prey	1.02	182	222	234	218	203	152
Number of pellets	396	52	72	72	72	72	52
Richness		7	10	11	12	10	9

Schlatter *et al*., 1980; Silva-Porto and Cerqueira, 1990; Vieira and Teixeira, 2008; Cadena-Ortíz *et al*., 2016). There was also a higher presence of invertebrates in the diet compared to temperate regions (Motta-Junior, 2006; Andrade *et al*., 2010). However, our results also show an effect of open habitat type and time on the composition of prey based on weights, as well as on presence of taxa.

It is expected to find more resources in late winter increasing owls' food availability and energy uptake (York *et al*., 2002), which may explain the higher pellet weight in late winter in our study. Higher consumption of prey could also be linked to the presence of offspring during the period (V. Oliveira, personal observation). Owls increased the hunting on vertebrate prey in urban open habitats in winter, which could optimize time spent on hunting while increasing the energy uptake (Nabte *et al*., 2008; Carevic *et al*., 2013). Additionally, the lower temperatures and higher moisture during winter months could decrease the invertebrate abundance (Zilio, 2006). Therefore, population dynamics of prey along the time in the different open habitats may influence *A. cunicularia* diet (Motta-Junior and Bueno, 2004). However, it was observed higher consumption of invertebrates in winter associated with the amount of rainfall in a study in *Araucaria* forest remnants (Silva, 2006), reinforcing the plasticity of owls to deal with population prey fluctuations associated with abiotic factors.

At lower taxonomic level, we observed specific effects of open habitats and time in prey selection inferring a plasticity in *A. cunicularia* use of resources. This generalist and opportunistic behaviour was described in other ecosystems (Menezes and Ludwig, 2013; Menezes and Meira, 2012; Silva, 2006; Zilio, 2006; Martins and Egler, 1990). In winter, there was lower presence of taxa, and the individuals fed mainly on mammals and on Blattodea and Coleoptera. Probably there was lower availability of prey in open habitats far from forest. This pattern is reinforced by the increase in the presence of invertebrate taxa in the diet mainly in warmer months, which could be related to the nesting area environment. Thus, the individuals could widen the amplitude of prey items whenever possible (Zilio, 2006; Menezes and Ludwig, 2013).

Besides, *A. cunicularia* is well adapted to human made environments profiting the most available prey and so minimizing the capture effort. It follows that rural open habitats closer to forests showed more presence of diverse consumed prey compared to urban habitats. However,

Table 3. *Athene cunicularia* consumed prey items in three open habitats collected in six months of 2015 and 2016 in southern Brazil. Total and relative biomasses of five classes of prey, and relative frequency of taxon presence of thirteen taxa. Rural 1 = open habitats near forest; Rural 2 = open habitats far from forest; Urban = urban open habitats.

Prey categories	Biomass (g)	Relative frequency (%)		
		Urban	Rural 1	Rural 2
Vertebrates	58.6	19	16	22
Amphibia		1	0	0
Aves		0.2	0.3	0.5
Mammalia		16	13	18
NI		0.7	2	1
Serpentes		0.5	1	2
Invertebrates	70.2	81	84	78
Blattodea		0.5	0	1
Coleoptera		32	33	32
Hymenoptera		12	14	8
Lepidoptera		0.2	0.7	1
Mollusca		0.7	0.7	2
NI		33	33	32
Oniscidea		0	0.5	0.5
Orthoptera		3	2	3
Vegetal	2.78			
Mineral	1.04			
Inorganic	0.03			
Total prey	132.65	402	398	411
Number of pellets	396	132	132	132
Richness		12	11	12

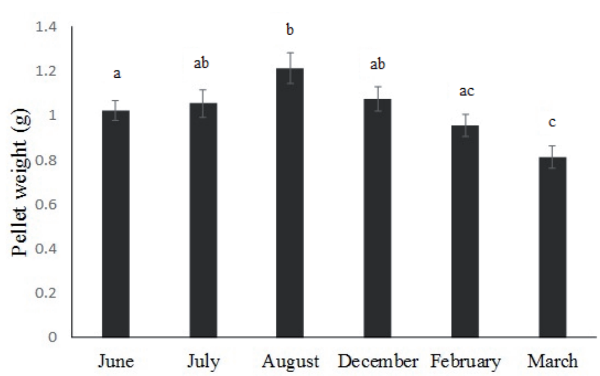

Figure 2. *Athene cunicularia* pellet weight means ± standard errors collected during six months in three open habitats of southern Brazil. Different letters indicate significant differences (P < 0.05).

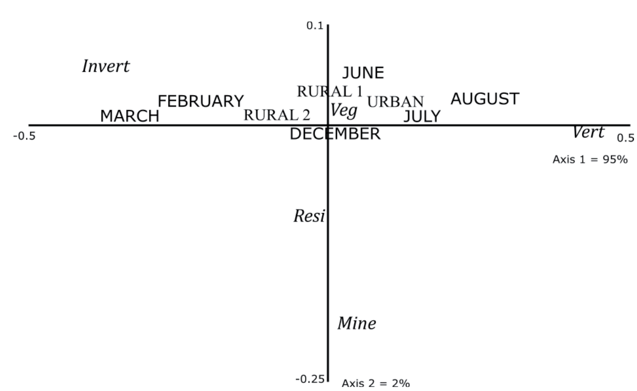

Figure 3. First and second principal axes of PCoA showing the composition of A. cunicularia pellets described by time and open habitat factors based on a chord distance dissimilarity matrix. Correlation coefficients of prey items with the first axis: Vertebrates (Vert) = 0.99; Invertebrates (Invert) = -0.98; Vegetal (Veg) = 0.02; Mineral (Mine) = 0.03; Residues (Resi) = -0.02.

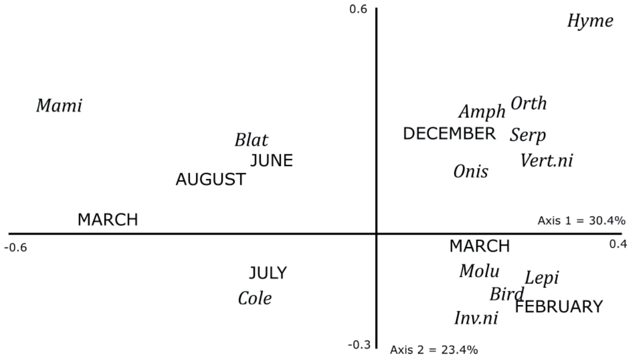

Figure 4. First and second principal axes of the PCoA performed with the composition of *A. cunicularia* pellets described by time factor based on the Jaccard similarity matrix (squared dissimilarities). Higher correlation coefficients of prey items with the first axis: Hymenoptera (Hyme) = -0.38; Mammal (Mami) = 0.88; Non-identified vertebrates (Vert.ni) = -0.12. Higher correlation coefficients of prey items with the second axis: Hymenoptera (Hyme) = -0.85; Mammal (Mami) = -0.27.

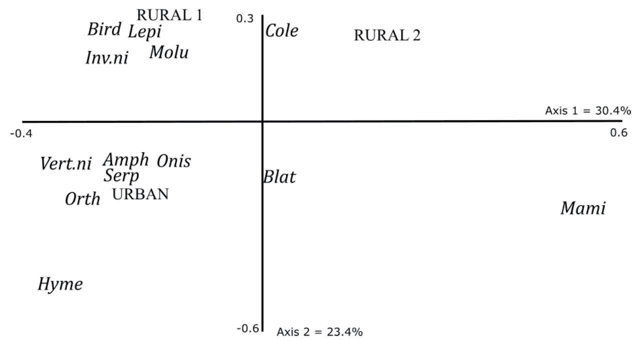

Figure 5. First and second principal axes of the PCoA performed with the composition of *A. cunicularia* pellets described by open habitat factor based on the Jaccard similarity matrix (squared dissimilarities). Higher correlation coefficients of prey items with the first axis: Hymenoptera (Hyme) = -0.38; Mammal (Mami) = 0.88; Non-identified vertebrates (Vert.ni) = -0.12. Higher correlation coefficients of prey items with the second axis: Hymenoptera (Hyme) = -0.85; Mammal (Mami) = -0.27.

there was a high turnover in prey composition between these two open habitats. More urbanized areas present a smaller variety of prey and greater use of rodents (murids essentially) by the owls. In less urbanized areas, the diet generally has a greater variety of prey and rodents became less important (Silva, 2006). In addition to urbanization, in our study we noticed that areas farther away from forest fragments have lower prey composition. This exchanging in food behaviour allows the maintenance of populations in changing environments by means of fitness maximization (Fisher, 1930; Grafen, 2014). The exchange of prey composition depending on local open habitat characteristics observed in our study may have resulted from niche complementarity, when dissimilarity of foraging behaviour increases fitness (Mason and Bello, 2013).

The turnover in prey composition of *A. cunicularia* allows it to occupy highly disturbed areas (Vieira and Teixeira, 2008; Carevic *et al*., 2013). However, it should be highlighted that few prey were more important to explain the open habitat and time differences found in our study, confirming the low food-niche breadth found in Argentine grasslands (Cavalli *et al*., 2014). Nevertheless, the wide spectrum of prey indicates that burrowing owl can adapt to temporal and spatial variation of resources, and can consequently colonize and expand species distribution along the highly heterogeneous human-modified landscape of southern Brazil.

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